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Standard Specification for
COLD-FORMED WELDED AND SEAMLESS CARBON STEEL STRUCTURAL TUBING IN ROUNDS AND SHAPES[1]

This Standard is issued under the fixed designation A 500; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This specification covers cold-formed welded and seamless carbon steel round, square, rectangular, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings, and for general structural purposes.

1.2 This tubing is produced in welded sizes with a maximum periphery of 64 in. (1626 mm) and a maximum wall of 0.500 in. (12.70 mm), and in seamless with a maximum periphery of 32 in. (813 mm) and a maximum wall of 0.500 in.

NOTE 1—Products manufactured to this standard may not be suitable for those applications such as dynamically loaded elements in welded structures, etc., where low-temperature notch-toughness properties may be important. For such applications the manufacturer should be consulted.

NOTE 2—The values stated in U.S. customary units are to be regarded as the standard.

2. Ordering Information

2.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately.

2.1.1 Quantity (feet or number of lengths),

2.1.2 Name of material (cold-formed tubing),

2.1.3 Method of manufacture (seamless or welded),

2.1.4 Grade (Table 1 and 2),

2.1.5 Size

2.1.6 Length (specific or random, see 12.1.3 or 12.2.3),

2.1.7 End condition (see 16.3),

2.1.8 Burr removal (see 16.3),

2.1.9 Certification (see 16.4),

2.1.10 Specification number,

2.1.11 End use, and

2.1.12 Special requirements.

3. Process

3.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4. Manufacture

4.1 The tubing shall be made by a seamless or welding process.

4.2 Welded tubing shall be made from flat-rolled steel by an automatic welding process producing a longitudinal weld with no addition of filler metal. The longitudinal butt joint of welded tubing shall be welded across its thickness in such a manner that the structural design strength of the tubing section is assured.

4.2.1 Structural tubing welded by electric-resistance methods is normally furnished without removal of inside flash.

4.3 The tubing may be stress relieved or annealed as is considered necessary by the manufacturer to conform to the requirements of this specification.

5. Heat Analysis

5.1 An analysis of each heat of open-hearth, basic-oxygen, or electric-furnace steel shall be made by the manufacturer. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 for heat analysis.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.09 on Pipe.

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6. Product Analysis

6.1 An analysis may be made by the purchaser from finished tubing manufactured in accordance with this specification, or an analysis may be made from flat-rolled stock of which the welded tubing is manufactured. When product analyses are made, two sample lengths from a lot of each 500 lengths or fraction thereof shall be selected. The specimens for chemical analysis shall be taken from the sample lengths in accordance with ASTM Method E 59, Sampling Steel and Iron for Determination of Chemical Composition.[2] The chemical composition thus determined shall conform to the requirements specified in Table 1 for product analysis.

6.2 In the event the chemical composition of one of the sample lengths does not conform to the requirements shown in Table 1 for product analysis, an analysis of two additional lengths selected from the same lot shall be made, each of which shall conform to the requirements shown in Table 1 for product analysis, or the lot is subject to rejection.

7. Tensile Requirements

7.1 The material, as represented by the test specimen, shall conform to the requirements as to tensile properties prescribed in Table 2.

8. Flattening Test

8.1 The flattening test shall be made on round structural tubing. A flattening test is not required for shaped structural tubing.

8.2 For welded round structural tubing, a specimen at least 4 in. (102 mm) in length shall be flattened cold between parallel plates in three steps, with the weld located at 90 deg from the line of direction of force. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the tubing. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces, except as provided for in 8.5, shall occur until the distance between the plates is less than one half of the original outside diameter of the tubing but is not less than five times the wall thickness of the tubing. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

8.3 For seamless round structural tubing 2⅜ in. (60.3 mm) outside diameter and larger, a section not less than 2½ in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility no cracks or breaks on the inside or outside surfaces, except as provided for in 8.5, shall occur until the distance between the plates is less than the value of "H" calculated by the following equation:

$$H = (1 + e)t/(e + t/D)$$

where:

H = distance between flattening plates, in.,

e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, 0.07 for Grade B, and 0.06 for Grade C),

t = nominal wall thickness of tubing, in., and

D = actual outside diameter of tubing, in.

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

8.4 Surface imperfections not found in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with Section 16.

8.5 When low D-to-t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

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[2] *Annual Book of ASTM Standards*, Part 12.

9. Test Methods

9.1 The tension specimens required by this specification shall conform to those described in the latest issue of ASTM Methods and Definitions A 370, for the Mechanical Testing of Steel Products, Supplementary Requirements II.[3]

9.2 The tension test specimen shall be taken longitudinally from a section of the finished tubing, at a location at least 90 deg from the weld in the case of welded tubing, and shall not be flattened between gage marks. If desired, the tension tests may be made on the full section of the tubing; otherwise, a longitudinal strip-test specimen as prescribed in Methods A 370 Supplementary Requirements II shall be used. The specimens shall have all burrs removed and shall not contain surface imperfections which would interfere with proper determination of the tensile properties of the metal.

9.3 The yield point shall be determined in accordance with one of the alternative methods described in Methods A 370.

10. Number of Tests

10.1 One tension test as specified in Section 9 shall be made from a length of tubing representing each lot.

10.2 The flattening test, as specified in Section 8 shall be made on one length of round tubing from each lot.

10.3 The term "lot" applies to all tubes of the same nominal size and wall thickness which are produced from the same heat of steel.

11. Retests

11.1 If the results of the mechanical tests representing any lot do not conform to a requirement as specified in Sections 7 and 8, retests may be made on additional tubing of double the original number from the same lot, each of which shall conform to the requirement specified; or the tubing represented by the test is subject to rejection.

11.2 In case of failure on retest to meet the requirements of Sections 7 and 8, the manufacturer may elect to retreat, rework, or otherwise eliminate the condition responsible for failure to meet the specified requirements. Thereafter, the material remaining from the lot originally represented may be tested and shall comply with all requirements of this specification.

12. Permissible Variations in Dimensions

12.1 *Round Structural Tubing*

12.1.1 *Diameter*—The outside diameter shall not vary more than ± 0.5 percent rounded to the nearest 0.005 in. (0.13 mm), of the nominal outside diameter size specified, for nominal outside diameter dimensions 1.900 in. (48.26 mm) and smaller, and plus and minus 0.75 percent rounded to the nearest 0.005 in. of the nominal outside diameter for nominal outside diameter dimensions 2.00 in. and larger. The outside diameter measurements shall be made at positions at least 2 in. (50.8 mm) from either end of the tubing.

12.1.2 *Wall Thickness*—The minimum wall thickness at any point of measurement on the tubing shall be not more than 10 percent less than the nominal wall thickness specified. The maximum wall thickness, excluding the weld seam of welded tubing, shall be not more than 10 percent greater than the nominal wall thickness specified.

12.1.3 *Length*—Structural tubing is normally produced in random mill lengths 5 ft (1.5 m) and over, in multiple lengths, and in specified mill lengths. Refer to Section 2. When specified mill lengths are ordered, the length tolerance shall be in accordance with Table 3.

12.1.4 *Straightness*—The permissible variation for straightness of round structural tubing shall be ⅛ in. times the number of feet (10.4 mm times the number of meters) of total length divided by 5.

12.2 *Square and Rectangular Structural Tubing*

12.2.1 *Outside Dimensions*—The specified dimensions, measured across the flats at positions at least 2 in. (50.8 mm) from either end of the tubing and including an allowance for convexity or concavity, shall not exceed the plus and minus tolerances shown in Table 4.

12.2.2 *Wall Thickness*—The tolerance for wall thickness exclusive of the weld area shall be plus and minus 10 percent of the nominal wall thickness specified. The wall thickness is to be measured at the center of the flat.

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[3] *Annual Book of ASTM Standards*, Parts 1, 2, 3, 4, 5, and 10.

12.2.3 *Length*—Square and rectangular structural tubing is normally produced in random mill lengths 5 ft and over, in multiple lengths, and in specified mill lengths. Refer Section 2. When specified mill lengths are ordered for square and rectangular structural tubing, the length tolerances shall be in accordance with Table 5.

12.2.4 *Straightness*—The permissible variation for straightness of square and rectangular structural tubing shall be ⅛ in. times the number of feet of total length divided by 5.

12.2.5 *Squareness of Sides*—For square or rectangular structural tubing, adjacent sides may deviate from 90 deg by a tolerance of plus or minus 2 deg max.

12.2.6 *Radius of Corners*—For square or rectangular structural tubing, the radius of any outside corner of the section shall not exceed three times the specified wall thickness.

12.2.7 *Twist*—The tolerances for twist or variation with respect to axial alignment of the section, for square and rectangular structural tubing, shall be as shown in Table 6. Twist is measured either by holding down one end of a square or rectangular tube on a flat surface plate with the bottom side of the tube parallel to the surface plate and noting the difference in height above the surface plate of the two corners at the opposite end of the bottom side of the tube or by measuring this difference on the heavier sections by a suitable measuring device. The difference in the height of the corners shall not exceed the values in Table 6. Twist measurements are not to be taken within 2 in. (50 mm) of either end of the product.

13. Special Shape Structural Tubing

13.1 The dimensions and tolerances of special shape structural tubing are available by inquiry and negotiation with the manufacturer.

14. Marking

14.1 Except as noted in 14.2, each length of structural tubing shall be legibly marked to show the following information: manufacturer's name, brand, or trademark; the specification number; and grade letter.

14.2 For structural tubing having a largest dimension of 4 in. (101.6 mm) or less, the information listed in 14.1 may be marked on a tag securely attached to each bundle.

15. Packing, Marking, and Loading

15.1 When specified in the order, contract, etc., packing, marking, and loading shall be in accordance with those procedures recommended by Recommended Practice A 700 for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment.[4]

16. Inspection

16.1 All tubing shall be subject to an inspection at place of manufacture to assure conformance to the requirements of this specification.

16.2 All tubing shall be free from injurious defects and shall have a workmanlike finish. Surface imperfections caused by handling marks, light die or roll marks, or shallow pits are not considered injurious defects, providing the imperfections are removable within the minimum wall permitted. The removal of such surface imperfections is not required. Welded tubing shall be free of protruding metal on the outside surface of the weld seam.

16.3 The ends of structural tubing, unless otherwise specified, shall be finished square cut and the burr held to a minimum. The burr can be removed on the outside diameter, inside diameter, or both, as a supplementary requirement. When burrs are to be removed, it shall be specified on the purchase order.

16.4 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished.

17. Rejection

17.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Tubing found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

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[4] *Annual Book of ASTM Standards*, Parts 1, 3, 4, and 5.

TABLE 1 **Chemical Requirements**

Element	Composition, %			
	Grades A and B		Grade C	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max	0.26	0.30	0.23	0.27
Manganese, max	...	...	1.35	1.40
Phosphorus, max	0.04	0.05	0.04	0.05
Sulfur, max	0.05	0.063	0.05	0.063
Copper, when copper steel is specified, min	0.20	0.18	0.20	0.18

TABLE 2 **Tensile Requirements**

Round Structural Tubing			
	Grade A	Grade B	Grade C
Tensile Strength, min, psi (MPa)	45 000 (310)	58 000 (400)	62 000 (427)
Yield Strength, min, psi (MPa)	33 000 (228)	42 000 (290)	46 000 (317)
Elongation in 2 in. (50.8 mm), min, %	25[a]	23[b]	21[c]
Shaped Structural Tubing			
	Grade A	Grade B	Grade C
Tensile Strength, min, psi (MPa)	45 000 (310)	58 000 (400)	62 000 (427)
Yield Strength, min, psi (MPa)	39 000 (269)	46 000 (317)	50 000 (345)
Elongation in 2 in. (50.8 mm), min, %	25[a]	23[b]	21[c]

[a] Applies to specified wall thicknesses 0.120 in. (3.05 mm) and over. For wall thicknesses under 0.120 in., the minimum elongation shall be calculated by the formula: percent elongation in 2 in. = $56t + 17.5$.

[b] Applies to specified wall thicknesses 0.180 in. (4.57 mm) and over. For wall thicknesses under 0.180 in., the minimum elongation shall be calculated by the formula: percent elongation in 2 in. = $61t + 12$.

[c] Applies to specified wall thicknesses 0.120 in. (3.05 mm) and over. For lighter wall thicknesses, elongation shall be by agreement with the manufacturer.

NOTE—The following table gives completed minimum values for longitudinal strip tests:

Wall thickness, in. (mm)	Elongation in 2 in. (50.8 mm), min, %	
	Grade A	Grade B
0.180 (4.57)	...	23
0.165 (4.19)	...	22
0.148 (3.76)	...	21
0.134 (3.40)	...	20
0.120 (3.05)	25	19.5
0.109 (2.77)	23.5	19
0.095 (2.41)	23	18
0.083 (2.11)	22	17
0.065 (1.65)	21	16
0.049 (1.24)	20	15
0.035 (0.89)	19.5	14

TABLE 3 Specified Mill Length Tolerances for Round Structural Tubing

	22 ft (6.7 m) and Under		Over 22 to 44 ft (6.7 to 13.4 m), incl	
	Over	Under	Over	Under
Length tolerance for specified mill length, in. (mm)	½ (12.7)	¼ (6.4)	¾ (19.0)	¼ (6.4)

TABLE 4 Outside Dimension Tolerances for Square and Rectangular Structural Tubing

Largest Outside Dimension, across flats, in. (mm)	Tolerance,[a] plus and minus, in. (mm)
2½ (63.5) and under	0.020 (0.51)
Over 2½ to 3½ (63.5 to 88.9), incl	0.025 (0.64)
Over 3½ to 5½ (88.9 to 139.7), incl	0.030 (0.76)
Over 5½ (139.7)	1 percent

[a] Tolerances include allowance for convexity or concavity. For rectangular sections, the tolerance calculated for the larger flat dimension shall also apply to the smaller flat dimension. This tolerance may be increased 50 percent when applied to the smaller dimension, if the ratio of the cross-sectional dimensions is 1.5 to 3, inclusive, and 100 percent when the ratio exceeds 3.

TABLE 5 Specified Mill Length Tolerances for Square and Rectangular Structural Tubing

	22 ft (6.7 m) and Under		Over 22 ft to 44 ft (6.7 to 13.4 m), incl	
	Over	Under	Over	Under
Length tolerance for specified mill length, in. (mm)	½ (12.7)	¼ (6.4)	¾ (19.0)	¼ (6.4)

TABLE 6 Twist Tolerances for Square and Rectangular Structural Tubing

Specified Dimension of Longest Side, in. (mm)	Maximum Twist in the First 3 ft (1 m) and in each additional 3 ft	
	in.	mm
1½ (38.1) and under	0.050	1.39
Over 1½ to 2½ (38.1 to 63.5), incl	0.062	1.72
Over 2½ to 4 (63.5 to 101.6), incl	0.075	2.09
Over 4 to 6 (101.6 to 152.4), incl	0.087	2.42
Over 6 to 8 (152.4 to 203.2), incl	0.100	2.78
Over 8 (203)	0.112	3.11

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